Title of Investigation:

Novel Light-Coupling of Non-Circular Fields of View with Flight-Proven, High-Efficiency, Single-Element Detectors for Spaceborne, Wide-Swath Imaging LIDAR (FY 2004 Extension)

Principal Investigator:

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Other In-house Members of the Team:

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External Collaborators:

Luis Ramos-Izquierdo (LRI Optical Design)

Initiation Year:

FY 2003

Aggregate Amount of Funding Authorized in FY 2003 and Earlier Years:

$0

Funding Authorized for FY 2004:

$38,000

Actual or Expected Expenditure of FY 2004 Funding:

Contracts: Luis Ramos-Izquierdo (LRI), $9,000; Fiber arrays, optics, and test support equipment, $27,000

Status of Investigation at End of FY 2004:

To be continued in FY 2005 with $25,000 in additional FY 2005 Director's Discretionary Fund (DDF) funding

Expected Completion Date:

December 2005

Purpose of Investigation:

Over the last decade, the Goddard Space Flight Center has become a world leader in the development of spaceborne laser altimeters. Goddard-developed instruments have flown on the Mars Orbiter Laser Altimeter (MOLA), Shuttle Laser Altimeter (SLA), Geoscience Laser Altimeter System (GLAS), and Mercury Laser Altimeter (MLA). Simultaneously, several companies worldwide have begun developing imaging laser altimeters, which measure an object's height, to meet the demand for high-quality topographical data over larger and larger areas. At the same time, Goddard technologists have begun focusing more on developing techniques for future space-borne imaging laser altimetry.

The Laser Vegetation Imaging Sensor (LVIS) instrument was designed as an imaging laser altimeter that uses a scanning receiver and transmitter quickly to map large areas of land from an aircraft platform. The LVIS instrument first flew in 1998 over Costa Rica. Building on the first flight's success, we have been investigating new approaches to migrate the wide-swath, imaging concept into space. However, without some method of efficiently coupling large fields of view (FOVs) onto flight-proven, highly sensitive detectors, allowable swath-widths will be greatly limited. Without such technological improvements, it will be difficult for Goddard to compete for future Earth Science missions, including those called for in NASA's Restless Planet Initiative and Solid Earth and Natural Hazards program.

The goals of the project's first year were to develop a wide FOV imaging lidar receiver that has no moving parts. The receiver uses a single detector and has greater then 70% optical throughput efficiency. This design has an order-of-magnitude reduction in background noise over a receiver based on conventional optics, resulting in an order-of-magnitude improved sensitivity. To achieve this, we designed a novel light pipe coupled with a densely packed linear fiber optic array to produce a uniform responsivity, wide-swath FOV receiver. This design allows the transmitter to be scanned across the receiver FOV, thus allowing for scanning with no moving parts in the receiver. By reducing the number of moving parts, we are able to improve the instrument's reliability and reduce its costs.

Accomplishments to Date:

We have completed the optical design for the wide swath FOV receiver and procured all of the required components. We discovered that we could optimize the optical transmission across the FOV using a unique optical component, a light pipe. This is a novel application of this device. These devices have been ordered for testing at Goddard. Further, we have completed a detailed optical ray trace analysis of the receiver concept to determine its performance and optimize its design. At this time, we are assembling the components in our test fixture. Once the light pipes are delivered, we can complete the optical assembly and validate the optical model and system design.

We designed a seven-fiber array system for ease of testing. Our design will allow for much larger fiber arrays than this, but the expense of testing a larger device would exceed what is necessary for proof of concept. Figure 1 shows the optical ray trace for the telescope focal plane, along with the light pipe and linear fiber array. Figure 2 shows the contour plot of the FOV response with and without the light pipe. The figure shows that the light pipe evenly distributes the incident light in the focal plane. Figure 3 shows the FOV response cross-section for various regions across the minor axis of the FOV.

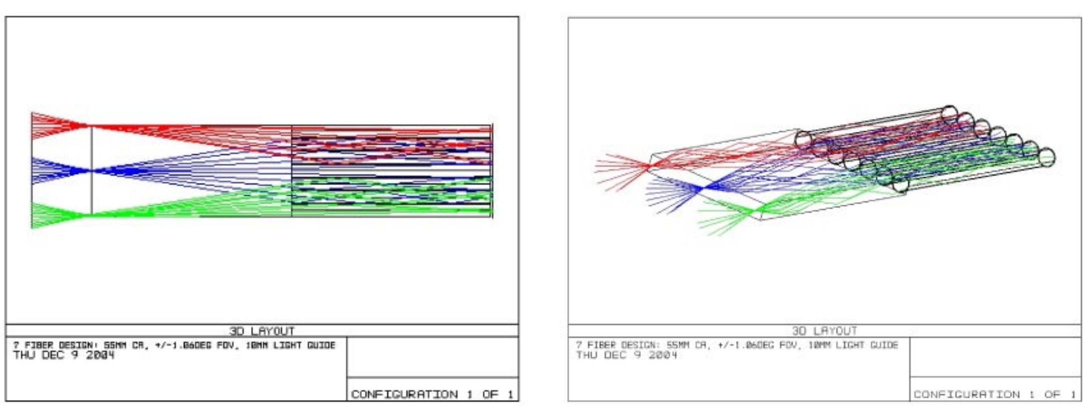

Figure 1. Telescope focal plane with light pipe guiding the received light to produce a uniform FOV response

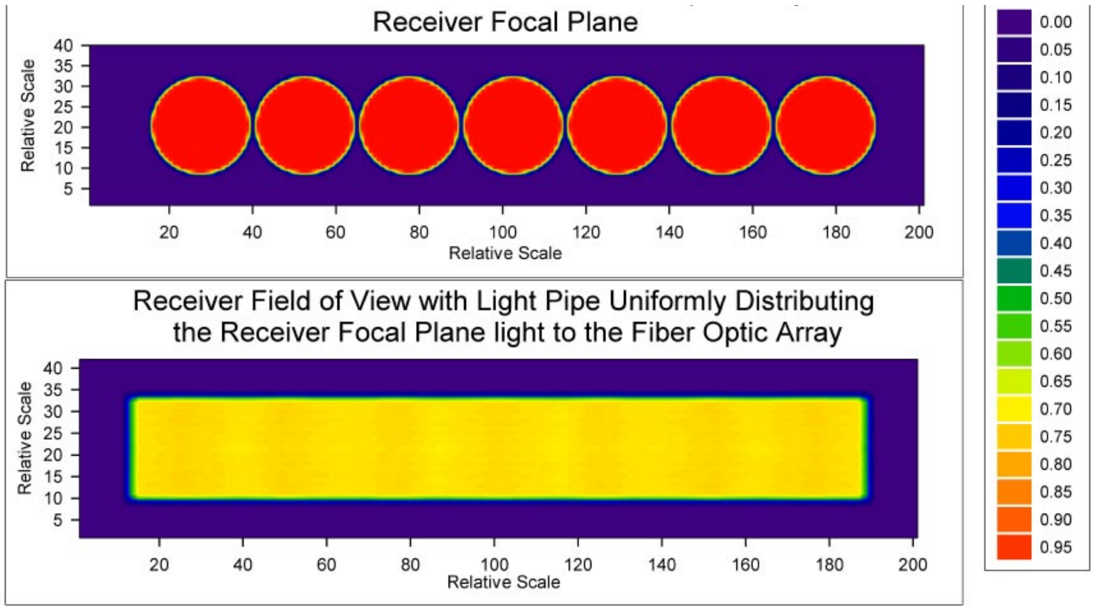

Figure 2. Comparison of linear fiber array FOV placed in a receiver focal plane to the light pipe FOV placed in the receiver focal plane. The plots show 100% transmission for the locations where the fibers are located in the fiber array plot and a uniformly shaped rectangular FOV with greater than 70% transmission over the entire desired FOV when the light pipe is added.

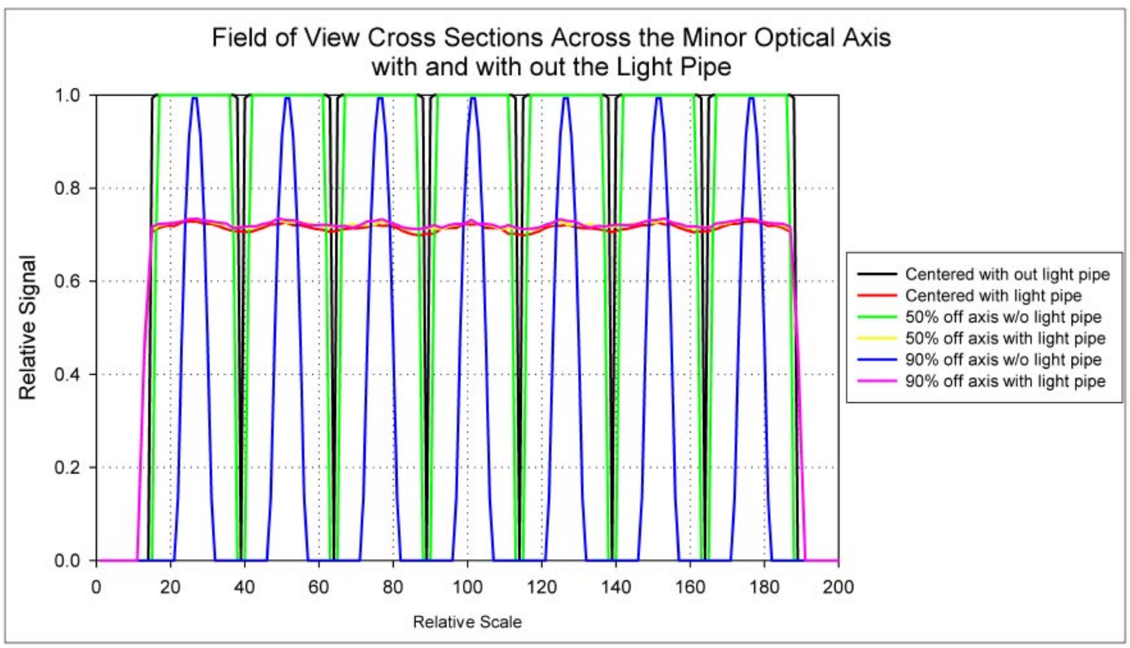

Figure 3. Relative signal intensity FOV response for various angular cross sections across in the minor axis of the FOV. The uniformity is very good for the FOV with the light pipe; however, the overall transmission is less than for the FOV with out the light pipe.

Planned Future Work:

During the year since we first proposed this investigation, our wide-swath imaging laser altimeter instrument concept has evolved to incorporate two-dimensional fiber optic arrays. This extension to a second dimension will allow for increased data resolution and coverage in the topographic images, expanding the field of potential applications for this imaging lidar approach. Supplemental Director's Discretionary (DDF) funding money was awarded to develop two-dimensional laser transmitter arrays to support this concept. We now will develop the matching receiver two-dimensional array to couple to these transmitter arrays.

Summary:

The FOV shaping optics approach will allow a wider FOV than what is possible with conventional optics. It also will reduce the background noise by an order-of-magnitude, thus enabling wider data swaths from space. Combining a novel light pipe/light condenser with custom assembly fibers allows us to shape the FOV to more exactly match the laser's swath size and shape to maximize the system's signal-to-noise ratio. This system requires no moving parts. Coupling two-dimensional transmitter and receiver arrays together allows optimized signal-to-noise ratio for each laser beam, thus allowing for more efficient sampling. This imaging lidar system requires no moving parts.

The wide FOV and high resolution possible with this system will enable space-borne imaging lidar to use lower power, less-risky laser transmitters, and smaller telescopes than what would be required using conventional optical designs. Further, it expands the potential application field for imaging lidars. The main goal of the first year is to successfully build and test the beam-shaped, wide-FOV receiver system with greater than 70% throughput efficiency. The second year will be devoted to successfully building and testing a coupled, two-dimensional laser-range imaging system.

The fabrication of the light pipe was much more difficult then we expected. Once the light pipes are received, they will have to be precisely aligned with the fiber arrays to make the FOV uniform and eliminate "dead spots" in the FOV. The fabrication of the tightly packed two-dimensional fiber arrays and the tight fiber-to-fiber spacing requirements will require close interaction between the vendor and us.